9.60 CONCRETE MATERIALS ISSUES

9.61 CONCRETE SAMPLING LOCATIONS

Concrete samples shall be taken as described in *Materials I.M. 327*. The sample location point shall be after plastic concrete has been placed on the grade, either by direct depositing from a batch truck or by use of a placer/spreader machine. On slipform paving projects, the optimum sample location is between placer/spreader and slipform paver machines. For safety considerations, samples may be taken from concrete deposited on the grade in front of the belt placer. Care should be taken to avoid sampling concrete that has been vibrated manually or mechanically. Samples should be taken at locations within the batch that appear to be representative.

9.62 TESTING PROCEDURES

When making test specimens, a sample should consist of about 0.03 cubic meters (one cubic foot) and should be remixed a minimum amount by use of a shovel to ensure uniformity. For routine air and slump tests, smaller samples may be used.

For standard methods of tests, refer to *Materials I.M. 327* (Sampling Freshly Mixed Concrete), *Materials I.M. 316* (Flexure Strength Tests), *Materials I.M. 317* (Slump Test), *Materials I.M. 318* (Air Content Test), and *Materials I.M. 328* (Making, Protecting, and Curing Beams).

9.63 AIR ENTRAINMENT IN PLASTIC CONCRETE

Specification 2301.02, B, 4 discusses the required percent of entrained air needed for concrete paving mixes. These percentages have been developed to allow for loss of entrained air as the plastic concrete is placed and consolidated as it goes through the paving operation. The concrete paving mixes have been developed to provide for consolidated concrete containing a 6% air content. Because the entrained air content percentages account for air loss through the paver, it is important to check the actual air loss through the paver to ensure that the amount of air loss is reasonably close to the anticipated loss. Air content should be checked behind the paver once each day for the first three days of paving. After that, air should be checked once per week behind the paver to verify the amount of air loss through the paver is consistent. The target air content for slip form pavement as determined by Materials I.M. 318 shall be 8.0%, plus or minus 2.0%, when measured on the grade just prior to consolidation. The air content for non slip form paving shall be 7.0% plus or minus 1.5%. Even when within the allowable air content range, the contractor should be making a reasonable effort to work toward the target air content. For slip form paving, adjustments to the mix should be made when the air content is less than 7% or greater than 9%. For non-slip form paving adjustments should be made when the air content is less than 6.0% or greater than 8.0%.

Aggregate Correction Factor

Per *Materials I.M.* 318, an adjustment to the target air content called an aggregate correction factor may be required for some quarries that have highly absorptive aggregates. The aggregate correction factor may be obtained from the District Materials Office. The target air content for PCC mixes utilizing these aggregates would be the specified target for the application plus the aggregate correction factor (see example below). Applying the aggregate correction factor when using aggregates from these quarries helps ensure that proper air content is achieved in the hardened concrete and also reduces excessive bleeding.

Example: For slip form PCC paving utilizing ready mixed concrete, specified air is 7.0% plus or minus 1.5% for the first day of paving. For an aggregate correction factor of 1.0%, the target would be 8.0% (8.0% equals the specified target of 7.0% plus the aggregate correction factor of 1.0%) plus or minus 1.5% .

The aggregate correction factor is in addition to any correction added for air content lost through the paver.

The following process will be used in verifying entrained air content in PCC paving mixes:

Control of Air Content
On projects where the contractor is performing quality control testing, the contractor and agency shall run side by side tests on the first air test of each day to ensure air meters are within the tolerance in IM 216. If the air tests are outside the tolerance, the air meters should be calibrated in accordance with IM 318. The contractor shall notify the engineer whenever an individual quality control test result is outside the tolerance for the target air content.

Verification
Lot acceptance shall be based on the agency verification test results on the unconsolidated mix on the grade. A lot is defined as the amount of a concrete mix placed since the last complying verification air content test.

Air Content Outside Tolerance
When a verification test result is outside the tolerance for the target air content, the contractor will be notified immediately. The contractor shall make immediate adjustments to the mix production and placement process to bring the air content back within tolerance. An air test will be immediately run behind the paver to aid in identifying the limits of the non-complying air. A test result between 5% and 8% behind the paver will be considered complying. This test will represent all concrete from the back of the paver back to the last verification test (or witnessed and documented quality control test when applicable).

All loads placed after the non-complying load will be tested until air content is within tolerance for two consecutive loads. Loads below the lower target air content tolerance by more than 0.5 % shall not be used. A price adjustment will be applied to all incorporated, non-complying loads that are out of tolerance. Removal and replacement may be required.

Air Content More Than 0.5% Below Lower Target Content
When the lot verification test result is below the lower target air content by more than 0.5 percent and the test run behind the paver indicates air content below 5% or above 8%, the contractor may elect to take concrete core samples from the pavement to define the portion of the lot that is non-complying. The lot will be divided into equal 200 square yard (170 square meter) sublots, from the last complying verification test, or witnessed and documented quality control test. A randomly located core will be identified in each sublot. Coring will be at the contractor's expense. The agency will direct and witness the taking of cores. The contractor may either:

1. Provide the agency with the cores for testing by Materials Laboratory Test Procedure 407.

2. Provide an independent laboratory for testing and a test procedure acceptable to the agency. The agency will take possession and ship the cores at the contractor's expense. Results will be directly reported to the agency and the testing will be at the contractor's expense.

Price Adjustments

Price adjustment or removal and replacement will be required for the following:

1. The load of concrete represented by the non-complying verification test.
2. The concrete between the load of concrete represented by the non-complying verification test and the test location behind the paver when the test behind the paver is between 5% and 8%.
3. All concrete between the non-complying verification test and the last complying verification test (or witnessed and documented quality control test when applicable) when the test behind the paver is less than 5% or greater than 8%.
4. When coring, sublots represented by cores with an entrained air content below 5.0 percent or above 8.0 percent.

Appendix 2-34(C) is the price adjustment table that lists price adjustments to be applied to concrete in which verification test results fall outside the specified limits.

9.64 CONCRETE VIBRATION AND CONSOLIDATION

Specification 2301.03, A, 3, a, 6, a requires vibration frequency to be maintained between 4000 and 8000 vibrations per minute for concrete paving finishing machines. To ensure proper consolidation of the plastic concrete, the vibration system used in the finishing machine should provide continuous and full coverage.

The depth of penetration into the concrete of internal vibrators should be set to mid slab height or as deep as possible while passing above any reinforcing steel. An operating position locking device should be provided so that no part of the vibrating unit can be lowered to the extent that it will come in contact with reinforcing steel or tie bars while paving.

Horizontal spacing of vibrators should not exceed the manufacturer's recommendation or 16 inches (410 mm), whichever is less. The Engineer may allow exceptions to this spacing in situations where structural elements of the paver make it impractical to maintain exact spacing. Vibrator spacing should not be increased for tie steel insertion or lack of adequate number of vibrators. Centerline spacing may be increased up to 30 inches

The longitudinal axis of the vibrator body should be mounted approximately parallel to the direction of paving with the exception that the trailing end of each vibrator shall be tilted downward to an approximate slope of 15 degrees below horizontal.

On large projects, greater than 50,000 square yards (40,000 square meters), an electronic monitoring device, which monitors and records the frequency of each vibrator on the paver, is required. The inspector will periodically check the electronic monitor by use of a manual device. The inspector will periodically check the monitor during the paving day and review, on a spot basis, the daily record of the vibration frequencies. Specification 2301.03, A, 3, a, 6, a requires submittal of vibration monitoring data daily for the first three days of paving and weekly thereafter. It is important that these

submittals occur because it gives the Engineer the opportunity to review the vibration data to ensure that vibrators are being operated within the allowable frequencies. Upon completion of the project, all vibration monitoring data should be submitted to the Office of Materials.

When a vibrator monitor is not required, vibrator readings should be taken and recorded at the start of concrete placement. Vibrators may be checked in the morning, before paving operation begins. This check can detect malfunctioning or dead vibrators. But, the frequencies will change as the hydraulic oil is heated once paving begins. A check of frequency levels needs to be made after the paver has been operating for some period of time, at least after the first 20 minutes or half hour. Readings should also be taken at least twice daily to check for mechanical failures or problems in the vibration system of the paver. When vibration monitoring is used, these checks are intended to verify that the vibration rate displayed by the monitor is the actual rate of vibration. When vibration monitoring is not used, vibration rate of each vibrator should be checked and recorded twice daily. Vibrator readings should be recorded on Form 830213 "Project Information/Paver Inspection." A copy of this form is included in *Appendix 9-3*.

If vibrator frequencies are greater than allowed by the specification, the Contractor should be informed to adjust the paving operations so that future measurements are within required specifications. Excessive vibration frequencies have been known to produce lower entrained air and premature concrete pavement deterioration with shorter pavement life. A price adjustment schedule for out of tolerance vibration can be found in *Appendix 2-34(C)*.

It is also helpful to watch for the presence of vibrator trails in the plastic concrete surface behind the transverse texturing operation (but before the curing compound application). These trails show in the surface of the plastic concrete by a deeper groove in the textured surface. This deeper texture follows the path of the vibrator. Many existing Portland cement concrete pavements are showing these "vibrator trails."

9.65 PAVEMENT THICKNESS CORES

Materials I.M. 346 describes procedures for coring PCC pavement for evaluating thickness requirements. The procedures are the basis for acceptance and payment of work. The Engineer will witness the coring and measure the cores immediately on the grade. If cores are not measured on the grade, the Engineer must take immediate possession of the core samples as they are drilled to ensure a proper chain of custody for acceptance. At no time should the contractor have possession of the cores prior to measurement by the Engineer.

9.66 PAVEMENT SMOOTHNESS

Pavement smoothness shall be evaluated in accordance with *Specification 2316*, *Specification 2317*, and *Materials I.M. 341*. See *Construction Manual 3.60* for additional information.

9.67 QUALITY MANAGEMENT CONCRETE (QM-C)

QM-C is the design, testing, placement, and monitoring of a Portland cement concrete mixture by a contractor in partnership with the owner for the purpose of making a superior product while promoting innovation and understanding.

The Iowa DOT requires QM-C on large paving projects greater than 50,000 square yards (42,000 square meters). It is mainly used on rural type paving projects, without a

lot of staging and/or handwork. The mix design is based on an optimized gradation, usually requiring three aggregates of coarse, intermediate, and fine (sand) sizes. QM-C mixes are designed for use in slip-form paving operations only. The optimized gradation allows easier slip-form placement without edge slump, especially on pavements with thicker pavement section (i.e. 12 inch thick interstate pavements). The QM-C mix design is typically coarser than Class C mix design and is not intended for handwork placement. The QM-C supplemental specifications require Class C concrete for handwork. However, in some cases the QM-C mix may be workable enough to be acceptable for handwork. With approval from the Project Engineer, a QM-C mix may be used for handwork.

Since three aggregates are typically required to produce the optimized gradation, QM-C mix designs are better suited on large rural paving projects where batches are proportioned in a central plant. Many ready mix producers do not have the capability to handle more than two aggregates, thus, it is usually not feasible to require QM-C on small projects that would typically use ready mixed concrete.

The biggest misconception of using the QM-C specification is that the contracting authority does not have to do testing since the contractor performs testing. IM 530 describes the testing required by the contracting agency. The contracting agency's test results must be used in the acceptance decision to comply with the requirement of the Materials Sampling and Testing Program. By not performing any verification testing, the owner may jeopardize federal aid on the project.

Since the contractor incurs additional costs for mix design, grade testing, and increased amount of coarse aggregate in QM-C mixes, Class C concrete may be more economical on smaller projects, urban projects, and projects with extensive staging. Class C concrete will perform equally well as the QM-C mix design and is sometimes better suited for certain placements and field situations.

Measurement and Payment

Measurement and payment can be difficult when using QM-C mixes. Payment for full-depth QM-C pavements is made with two items. The first item is a QM-C cubic yard (cubic meter) item. This item is intended to compensate the contractor for the development of the Concrete Design Mixture (CDM) as well as the testing and process control necessary for production of the mix. The second item is a square yard (square meter) item intended to compensate the contractor for the pavement. An incentive payment is applied to the square yard (square meter) item based upon the aggregate gradation achieved in the CDM throughout the project. However, the incentive only applies to the area of pavement placed using the CDM.

Payment for PCC overlays using QM-C is made with three items. The first item is the QM-C cubic yard (cubic meter) item, and measurement and payment are the same as that used for full-depth pavements. The second item is a QM-C Furnish item. This item is intended to compensate the contractor for the cubic yards (cubic meters) of QM-C mix used on the project. Finally, the third item is a QM-C Placement item. This item is intended to compensate the contractor for placement of the QM-C mix.

NOTE: *For overlays, the incentive payment for gradation is applied to both the QM-C Furnish item and the QM-C Placement item.*

The square meter (yard) items for QM-C are plan quantity and typically would not need to be measured. However, because the Coarseness/Workability incentive payment only applies to the slip formed portion of the square meter (yard) item, the area of all hand pours must be measured and subtracted from the plan quantity to determine the appropriate Coarseness/Workability incentive payment. This is further complicated by the contractor's option to use the QM-C mix for non-QM-C pavements on a project. See *Appendix 9-7* for guidance on payment for PCC pavements under the QM-C specification.

Materials I.M. 530 requires submittal of all QM-C quality control charts and records to the Project Engineer. The Project Engineer should forward copies of these files to the Office of Materials upon completion of the project.